



POLITÉCNICA

INTERNATIONAL  
CAMPUS OF  
EXCELLENCE

COORDINATION PROCESS OF  
LEARNING ACTIVITIES  
PR/CL/001



E.T.S. de Ing. de Caminos  
Canales y P.

# ANX-PR/CL/001-01

## LEARNING GUIDE

### SUBJECT

**43000391 - Dynamic And Seismic Analysis Of Structures**

### DEGREE PROGRAMME

04AG - Master Universitario En Ingenieria De Caminos, Canales Y Puertos

### ACADEMIC YEAR & SEMESTER

2025/26 - Semester 2

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## 1. Description

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### 1.1. Subject details

<b>Name of the subject</b>	43000391 - Dynamic And Seismic Analysis Of Structures
<b>No of credits</b>	4.5 ECTS
<b>Type</b>	Optional/elective
<b>Academic year of the programme</b>	Second year
<b>Semester of tuition</b>	Semester 4
<b>Tuition period</b>	February-June
<b>Tuition languages</b>	English
<b>Degree programme</b>	04AG - Master Universitario en Ingeniería de Caminos, Canales y Puertos
<b>Centre</b>	04 - E.T.S. De Ing. De Caminos Canales Y P.
<b>Academic year</b>	2025-26

## 2. Faculty

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### 2.1. Faculty members with subject teaching role

<b>Name and surname</b>	<b>Office/Room</b>	<b>Email</b>	<b>Tutoring hours *</b>
Ivan Muñoz Diaz	Lab Estructuras	ivan.munoz@upm.es	W - 11:00 - 14:00 Th - 11:00 - 14:00
Luis Francisco Plaza Beltran	Structures Lab	luis.plaza.beltran@upm.es	F - 15:30 - 19:30
Juan Carlos Mosquera Feijoo (Subject coordinator)	Lab Sist Intel	juancarlos.mosquera@upm.es	W - 10:15 - 13:45 Th - 10:15 - 13:45 Laboratorio de Sistemas Inteligentes, 2nd floor

Antonio Jose Madrid Ramos	Lab estructuras	antoniojose.madrid@upm.es	Sin horario. Available upon request
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\* The tutoring schedule is indicative and subject to possible changes. Please check tutoring times with the faculty member in charge.

### 2.3. External faculty

Name and surname	Email	Institution
Luis Cueto-felgueroso Landeira	luis.cueto@upm.es	ETSICCP, Dep Hidráulica, energía y medio ambiente
Sandro Andrés Martínez	sandro.andres@upm.es	ETSICCP, Depto Hidráulica, energía y Medio ambiente

## 3. Prior knowledge recommended to take the subject

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### 3.1. Recommended (passed) subjects

- Metodos Computacionales En Ingenieria Civil

### 3.2. Other recommended learning outcomes

- Skills on MatLab

- Mathematical analysis. Differential and Integral Calculus. Vector and Tensor Algebra. Vector and Tensor Analysis. Ordinary differential equations. Partial differential equations. Mechanics. Strength of Materials. Structural analysis. Computational Mechani

## 4. Skills and learning outcomes \*

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### 4.1. Skills to be learned

CB06 - Poseer y comprender conocimientos que aporten una base u oportunidad de ser originales en el desarrollo y/o aplicación de ideas, a menudo en un contexto de investigación

CB07 - Que los estudiantes sepan aplicar los conocimientos adquiridos y su capacidad de resolución de problemas en entornos

CB09 - Que los estudiantes sepan comunicar sus conclusiones y los conocimientos y razones últimas que las sustentan a públicos especializados y no especializados de un modo claro y sin ambigüedades

CB10 - Que los estudiantes posean las habilidades de aprendizaje que les permitan continuar estudiando de un modo que habrá de ser en gran medida autodirigido o autónomo.

CE22 - Conocimiento y capacidad para el análisis estructural mediante la aplicación de los métodos y programas de diseño y cálculo avanzado de estructuras, a partir del conocimiento y comprensión de las solicitaciones y su aplicación a las tipologías estructurales de la ingeniería civil. Capacidad para realizar evaluaciones de integridad estructural.

CE32 - Capacidad para aplicar los conocimientos técnicos en la evaluación de proyectos, obras e infraestructuras dentro del ámbito de la ingeniería civil.

CE33 - Capacidad para aplicar los conocimientos técnicos en actividades de I+D+i dentro del ámbito de la ingeniería civil.

CE34 - Capacidad para integrar y aplicar los conocimientos técnicos en asesoría, análisis, cálculo, proyecto, construcción, y evaluación técnica de infraestructuras de ingeniería civil.

CE38 - Capacidad para integrar y aplicar los conocimientos técnicos en asesoría, análisis, diseño y modelización físico-matemática en ingeniería estructural.

CE39 - Capacidad predictiva para optimización de soluciones en ingeniería estructural.

CGP01 - Capacitación científico-técnica y metodológica para el reciclaje continuo de conocimientos y el ejercicio de las funciones profesionales de asesoría, análisis, diseño, cálculo, proyecto, planificación, dirección, gestión, construcción, mantenimiento, conservación y explotación en los campos de la ingeniería civil. Incorpora las competencias CB6, CB7 y CB8

CGP06 - Conocimiento para aplicar las capacidades técnicas y gestoras en actividades de I+D+i dentro del ámbito de la ingeniería civil. Incorpora las competencias CB6, CB7 y CB8.

CGP11 - Capacidad para el proyecto, ejecución e inspección de estructuras (puentes, edificaciones, etc.), de obras de cimentación y de obras subterráneas de uso civil (túneles, aparcamientos), y el diagnóstico sobre su integridad. Incorpora las competencias CB6, CB7 y CB8.

CGP12 - Capacidad para planificar, diseñar y gestionar infraestructuras, así como su mantenimiento, conservación y explotación. Incorpora las competencias CB6, CB7 y CB8.

CGP18 - Conocimientos adecuados de los aspectos científicos y tecnológicos de métodos matemáticos, analíticos y numéricos de la ingeniería, mecánica de fluidos, mecánica de medios continuos, cálculo de estructuras, ingeniería del terreno, ingeniería marítima, obras y aprovechamientos hidráulicos y obras lineales. Incorpora las competencias CB6, CB7 y CB8.

CT1 - Capacidad de preparar y presentar comunicaciones orales, escritas y gráficas, estructurada y argumentadamente. Desarrolla la competencia transversal 4ª del Real Decreto.

CT2 - Polivalencia y capacidad de aprendizaje autónomo. Desarrolla la competencia transversal 5ª del Real Decreto.

CT3 - Capacidad de comunicación técnica oral y escrita en lengua inglesa. Desarrolla la competencia transversal 1ª de la normativa UPM.

CT4 - Capacidad de organizar y dirigir los esfuerzos de un equipo. Desarrolla la competencia transversal 5ª de la normativa UPM.

CT5 - Capacidad de ejercer las funciones profesionales de proyecto, cálculo, evaluación técnica, planificación y gestión técnica mediante el uso de normativa europea e internacional. Desarrolla la competencia transversal 7ª de la normativa UPM.

CT8 - Capacidad de diseñar, analizar e interpretar experimentos relevantes en ingeniería civil.

## 4.2. Learning outcomes

RA85 - SO2 The student acquires the fundamentals of static and dynamic experimental techniques in structural engineering, and understands the structural implications of taken measurements.

RA210 - Conoce y aplica herramientas de cálculo numérico a problemas de ingeniería civil.

RA17 - Modeliza y dimensiona elementos estructurales aplicando la teoría clásica de la Elasticidad y su extensión a régimen dinámico y a plasticidad de secciones, aplicando métodos analíticos y numéricos.

RA120 - Conoce la influencia de las diversas causas de no linealidad en el análisis dinámico de estructuras y los métodos de cálculo aplicables.

RA20 - Proyecta y evalúa cimentaciones y obras geotécnicas, y planifica su ejecución y preservación de integridad aplicando modelos y criterios orientados a la optimización resistente, funcional y medioambiental.

RA16 - Planifica, evalúa, gestiona y explota infraestructuras y recursos hidráulicos superficiales y subterráneos, aplicando modelos avanzados y criterios de gestión integral, con la incorporación de los efectos y condicionantes medioambientales.

RA114 - Conoce los comportamientos viscoelástico y elastoplástico de los sólidos

RA1 - Formula y resuelve problemas matemáticos y numéricos avanzados de ingeniería civil, identificando sus diferentes componentes científicos y técnicos y seleccionando y acoplado con eficacia los métodos de resolución.

RA129 - Modela y dimensiona elementos continuos y estructurales sometidos a acciones dinámicas mediante métodos analíticos y numéricos.

\* The Learning Guides should reflect the Skills and Learning Outcomes in the same way as indicated in the Degree Verification Memory. For this reason, they have not been translated into English and appear in Spanish.

## 5. Brief description of the subject and syllabus

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### 5.1. Brief description of the subject

#### Unit I. Structural dynamics. General concepts

Chapter 1. Mathematical and dynamic modelling. Discretization methods

Mathematical model. Matrix analysis of structures. Dynamic model. Space and time discretization. Discrete systems. Degrees of freedom. Continuous systems. Lumped-mass method. Generalized displacement method. The finite element method. Equations of motion. Objectives of the dynamic analysis.

#### Unit II. Time domain analysis of Single degree-of-freedom systems

Chapter 2. Free vibrations

Undamped vibrations. Damped vibrations. Logarithmic decrement. Vibrations with dry friction.

Chapter 3. Response to harmonic excitations and periodic excitations

Undamped vibrations. Damped vibrations. Amplification factor. Resonant response. Vibration-measuring instruments. Forces transmitted to the ground and vibration isolation. Damping measurement.

Exponential form of the solution. Complex frequency response function (CFRF).

Chapter 4. Responses to impulsive and arbitrary dynamic loading

Impulsive excitation. Maximum response analysis. Response to shortduration impulsive loadings. Response to an arbitrary dynamic loading. Convolution integrals. Numerical approach.

#### Unit III. Time domain analysis of multi-degree-of-freedom systems

Chapter 5. Multi-degree-of-freedom systems. Modelling and analysis. Vibration frequencies and mode shapes

Selection of dynamic degrees of freedom. Direct approach. Variational formulation. Stiffness and mass matrices. Damping matrix. External loading.

Vibration frequencies and mode shapes. Characteristic load. Modal Orthogonality. Normalizing the mode shapes. Modal coordinate transformation methods. Tracking methods.

Chapter 6. Analysis of vibration frequencies and mode shapes

NoUndamped vibrations. Vibration frequencies and mode shapes. Interpretation of mode shapes. Characteristic load. Modal Orthogonality. Normalizing the mode shapes. Calculation of vibration frequencies and mode shapes. Modal coordinate transformation methods. Tracking methods.

Chapter 7. Response Analysis. Mode superposition method.

Normal coordinates. Uncoupling the equations of motion. Dynamic response. Conditions of modal orthogonality with respect to the damping matrix. Construction of the damping matrix.

Chapter 8. Vibration alleviation. Tuned mass dampers

Vibration isolation. Fundamentals of TMD. Example of TMD design.

#### **Unit IV. Frequency-domain analysis**

Chapter 9. Fundamentals of the dynamic analysis in the frequency domain

Fourier series representation of a periodic loading. Frequency Response Function. Fourier series and the Fourier integral. Fundamental equation of frequency domain analysis. Aliasing and other numerical difficulties with the Fourier transform.

Chapter 10. Frequency-domain method of response analysis

CFRF. Response analysis in the frequency domain when the vibration modes are known. Response analysis in the frequency domain with unknown modes. Complex frequency-response function matrix

#### **Unit V. Elements of earthquake engineering**

Chapter 11. Fundamentals of seismology

Sources of earthquakes. The seismic cycle. Plate tectonics. Seismic zones. Faults and earthquakes. Seismic waves. Earthquake records.

#### Chapter 12. Seismic risk

Seismic risk and related concepts. Parameters related to earthquakes: intensity, magnitude, moment, displacement, velocity, acceleration. Scales. Relations. Seismic hazard assessment. Deterministic methods. Probabilistic methods. Zoned and not zoned methods. Expression of results.

#### Chapter 13. Design earthquake. Response spectrum analysis

Design earthquake. Response spectra. Response spectrum analysis (RSA)

#### Chapter 14. Seismic Codes

Spanish Earthquake-resistant Construction Code for buildings and Eurocode 8.

Samples and exercises.

## 5.2. Syllabus

1. Unit I. Structural dynamics. General concepts
2. Unit II. Time domain analysis of Single degree-of-freedom systems
3. Unit III. Time domain analysis of multi-degree-of-freedom systems
4. Unit IV. Frequency-domain analysis
5. Unit V. Elements of earthquake engineering

## 6. Schedule

### 6.1. Subject schedule\*

Week	Type 1 activities	Type 2 activities	Distant / On-line	Assessment activities
1	<b>Chapters 1 and 2</b> Duration: 03:00 Lecture			
2	<b>Chapter 3</b> Duration: 02:00 Lecture		<b>Exercise classes, problem classes, quizzes</b> Duration: 01:00 Problem-solving class	
3	<b>Chapter 4</b> Duration: 01:00 Lecture		<b>Exercise classes, problem classes, quizzes</b> Duration: 01:00 Service learning  <b>Problem-based, learning, group work</b> Duration: 01:00 Service learning	<b>Special assignment Chapters 1 to 4</b> Individual work Progressive assessment Presential Duration: 01:00
4	<b>Chapter 5</b> Duration: 01:00 Lecture		<b>Exercise classes, problem classes, quizzes,</b> Duration: 02:00 Problem-solving class	
5	<b>Chapter 6</b> Duration: 02:00 Lecture		<b>Exercise classes, problem classes, quizzes</b> Duration: 01:00 Problem-solving class	<b>Special assignment Chapters 5 and 6</b> Individual work Progressive assessment Not Presential Duration: 01:00
6	<b>Chapter 7</b> Duration: 01:00 Lecture		<b>Problem-based, learning, group work</b> Duration: 02:00 Service learning	
7	<b>Chapter 8</b> Duration: 01:00 Lecture		<b>Exercise classes, problem classes, quizzes</b> Duration: 02:00 Problem-solving class	<b>Special assignment Chapters 7 and 8</b> Group presentation Progressive assessment Presential Duration: 02:00
8	<b>Chapter 9</b> Duration: 02:00 Problem-solving class		<b>Exercise classes, problem classes, quizzes</b> Duration: 01:00 Service learning	
9	<b>Chapter 9</b> Duration: 01:00 Lecture		<b>Problem-based learning, group work</b> Duration: 02:00 Service learning	
10	<b>Chapter 10</b> Duration: 02:00 Lecture		<b>Exercise classes, problem classes, quizzes</b> Duration: 01:00 Problem-solving class	<b>Special assignment Chapters 7 and 8</b> Group presentation Progressive assessment Presential Duration: 02:00

11	<b>Chapter 11</b> Duration: 02:00 Lecture		<b>Exercise classes, problem classes, quizzes</b> Duration: 01:00 Problem-solving class	
12	<b>Chapter 12</b> Duration: 02:00 Lecture		<b>Exercise classes, problem classes, quizzes</b> Duration: 01:00 Problem-solving class	
13	<b>Chapter 13</b> Duration: 02:00 Lecture		<b>Exercise classes, problem classes, quizzes</b> Duration: 01:00 Problem-solving class	
14	<b>Chapter 14</b> Duration: 02:00 Lecture		<b>Exercise classes, problem classes, quizzes</b> Duration: 01:00 Problem-solving class	<b>Special assignment Chapters 12 to 14</b> Group presentation Progressive assessment Presential Duration: 01:00
15	<b>Chapter 14</b> Duration: 02:00 Lecture			<b>Final exam</b> Written test Progressive assessment Presential Duration: 03:00
16				
17				<b>End-of-year exam</b> Written test Global examination Presential Duration: 03:00

Depending on the programme study plan, total values will be calculated according to the ECTS credit unit as 26/27 hours of student face-to-face contact and independent study time.

## 7. Activities and assessment criteria

### 7.1. Assessment activities

#### 7.1.1. Assessment

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
3	Special assignment Chapters 1 to 4	Individual work	Face-to-face	01:00	5%	1 / 10	CB06 CB07 CT2 CE22 CT1 CB09 CB10
5	Special assignment Chapters 5 and 6	Individual work	No Presential	01:00	10%	1 / 10	CT4 CE22 CT3 CB06 CB07
7	Special assignment Chapters 7 and 8	Group presentation	Face-to-face	02:00	5%	1 / 10	CGP01 CGP11 CGP12 CT2 CT3 CT1 CB09 CB10
10	Special assignment Chapters 7 and 8	Group presentation	Face-to-face	02:00	10%	1 / 10	CT4 CT2 CT3 CT1 CB10
14	Special assignment Chapters 12 to 14	Group presentation	Face-to-face	01:00	10%	1 / 10	CGP01 CGP11 CGP12 CE33 CT4 CT2 CT3 CT5 CB10

15	Final exam	Written test	Face-to-face	03:00	60%	5 / 10	CT4 CT2 CE22 CT3 CT1 CT5 CB06 CB07 CB09 CB10
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### 7.1.2. Global examination

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
17	End-of-year exam	Written test	Face-to-face	03:00	100%	5 / 10	CGP01 CGP11 CGP12 CT4 CT2 CE22 CE33 CT3 CT1 CT5 CB06 CB07 CB09 CB10

### 7.1.3. Referred (re-sit) examination

Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
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Extraordinary end-of-year exam	Written test	Face-to-face	03:00	100%	5 / 10	CE33 CT4 CT2 CE22 CT3 CT1 CT5 CB06 CB07 CB09 CB10
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## 7.2. Assessment criteria

Each exercise counts ten points. The exam score is the weighted average of the scores of the exercises. Passing grade is five out of ten points

## 8. Teaching resources

### 8.1. Teaching resources for the subject

Name	Type	Notes
Basic references	Bibliography	Preumont, A. (2013): Twelve Lectures on Structural Dynamics, Université Libre de Bruxelles. Chopra, A.K. (2012): Dynamics of structures. Structures: Theory and Applications to Earthquake Engineering, Prentice Hall, 4th Ed. 

Complementary references	Bibliography	Clough, R.W.; Penzien, J. (2010): Dynamics of structures Mac CEN (2011): Eurocódigo 8: Proyecto de estructuras sismorresistentes UNE-EN 1998-1. Humar, J. (2012). Dynamics of structures. CRC press.
Further references	Bibliography	Bolt, B. A. (1981): Terremotos. Serie Reverté Ciencia y Sociedad. Min de Fomento (2003): Norma de Construcción Sismorresistente NCSE-02: Parte General y de edificación. Min de Fomento (2008): Norma de Construcción Sismorresistente: Puentes NCSP-07.
References on earthquake engineering	Bibliography	Eurocode 8: Seismic Design of Buildings. Worked examples JRC European Commission, 2012. Naeim, F. The seismic design Handbook Van Nostrand Reinhold, 2001.
Electronic platforms	Web resource	Moodle Readiness to both online or on-site teaching
Complementary reading	Bibliography	Paultre, P. (2013). Dynamics of structures. John Wiley & Sons. Kelly, T. E., Skinner, R. I., & Robinson, W. H. (2010). Seismic isolation for designers and structural engineers. NICEE.

## 9. Other information

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### 9.1. Other information about the subject

Supplementary teaching materials and resources may also be available on Learning-based-system platforms (e.g., Moodle, Teams...) .